West Fork White River, Muncie to Hamilton-Marion County Line TMDL for *E. coli* Bacteria

Sources Report

FINAL

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May 2, 2003

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1. Introduction

1.1. Purpose of Document

The West Fork White River (WFWR) from Muncie to the Hamilton-Marion County line drains approximately 1,100 square miles in central Indiana (Figure 1). Several segments of this stretch of the WFWR appear on Indiana's section 303(d) list of impaired waters for failing to fully support the state's recreation use (Table 1 and Figure 2)*. These impairments were identified based on data collected by the Indiana Department of Environmental Management (IDEM) during the 1996 and 2001 water quality surveys. Data from those surveys resulted in violations of the *Escherichia Coli (E. coli)* standard. *E. coli* is a bacterium that indicates the presence of human sewage and animal manure. It can enter rivers through direct permitted discharges, combined sewer overflows (CSOs), illicit and failing septic systems and storm runoff carrying wastes from wildlife, domestic and agricultural animals. *E. coli* is also an indication of the possible presence of other disease causing organisms or pathogens.

Table 1. Impaired waterbodies listed for *E. coli* from the 1998 section 303(d) list in the WFWR watershed above the Hamilton-Marion County line.

Stream Segment	Waterbody ID	Designated Use	Support Status
West Fork White River (Muncie to Madison County)	IN05120201030	Recreation	Impaired
West Fork White River (Madison County)	IN05120201050	Recreation	Impaired
West Fork White River (Hamilton County)	IN05120201050	Recreation	Impaired
Killbuck Creek	IN05120201040	Recreation	Impaired
Pipe Creek	IN05120201060	Recreation	Impaired
Stoney Creek	NA	Recreation	Impaired
Cicero Creek	IN05120201080	Recreation	Impaired
Duck Creek	IN05120201070	Recreation	Impaired

Sources: IDEM, 1998a; IDEM, 1998b.

* Indiana's current section 303(d) list was submitted on April 15, 1998 and approved by USEPA in 1999. A draft 2002 section 303(d) list is currently being reviewed by USEPA.

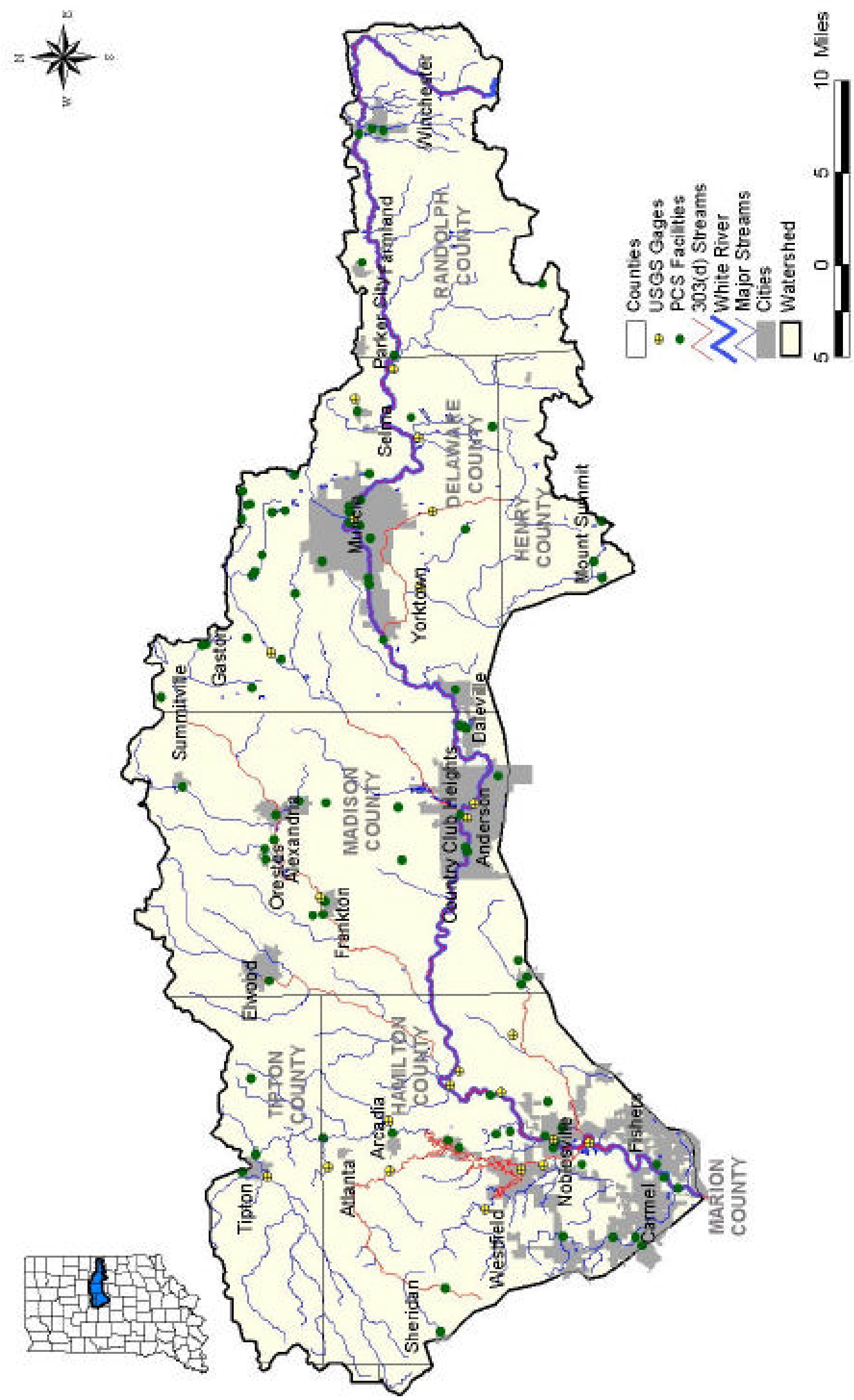

Figure 1. Political map of the WFWR watershed above the Hamilton-Marion County line.

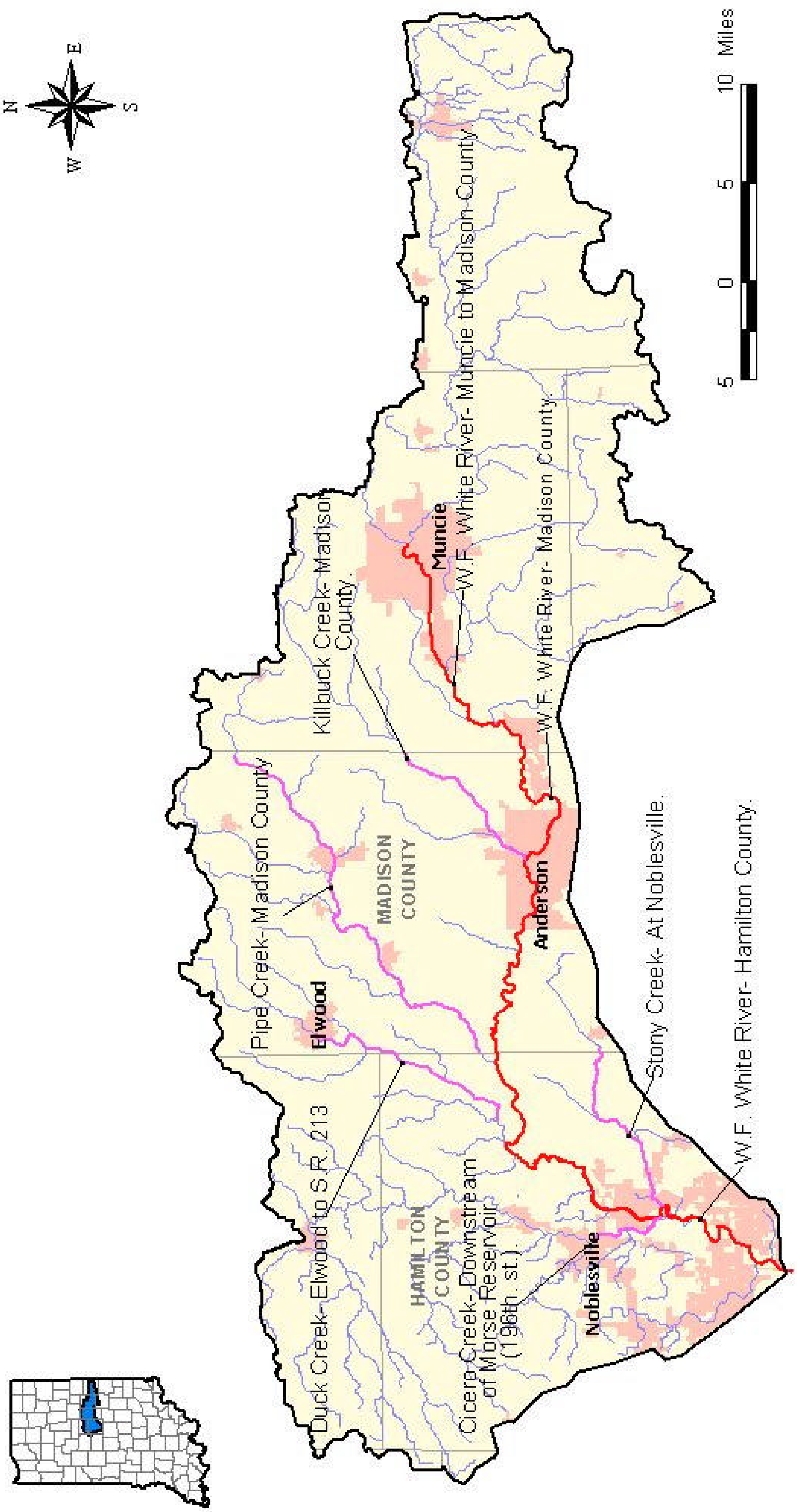

Figure 2. Waters in the WFWR watershed above the Hamilton-Marion County line that are listed for *E. coli*.

The Clean Water Act and U.S. Environmental Protection Agency (USEPA) regulations require that states develop Total Maximum Daily Loads (TMDLs) for all waters on the section 303(d) lists. A TMDL is the sum of the allowable amount of a single pollutant that a waterbody can receive from all contributing point and nonpoint sources and still support its designated uses. IDEM is in the process of developing *E. coli* TMDLs for the WFWR above the Hamilton-Marion County line. The overall goals and objectives of the project are to

- Further assess the water quality of the WFWR and identify key issues associated with the impairments and potential pollutant sources.
- Use the best available science to determine the maximum load of *E. coli* that the river can receive and still fully support all of its designated uses.
- Use the best available science to determine current loads and sources of *E. coli*.
- If current loads exceed the maximum allowable load, determine the load reduction that is needed.
- Identify feasible and cost-effective actions that can be taken to reduce loads.
- Inform and involve the public throughout the project to ensure that key concerns are addressed and the best available information is used.
- Submit a final TMDL report to USEPA for review and approval.

A previous report described the physical setting of the WFWR watershed and discussed the spatial and temporal extent of *E. coli* concentrations (Tetra Tech, 2002). This Sources Report identifies and describes the nature, location, and magnitude of potential sources of *E. coli* bacteria that are present in the WFWR watershed. The following categories of sources are discussed:

- Wastewater treatment plants
- Combined sewer overflows
- Storm water runoff
- Septic systems
- Livestock and manure
- Wildlife
- Domestic pets

Annual loads of *E. coli* from each of these sources are estimated using currently available information. A number of assumptions have had to be made due to a lack of complete information. IDEM is requesting feedback from readers regarding these assumptions so that they can be revised, if necessary, for use in the final TMDL. Once all comments have been received, the results of the source assessment will be used to setup and calibrate a water quality model that will simulate the effects of the *E. coli* loading on instream water quality. The final TMDL report will combine the results of all previous reports and address the regulatory requirements of the TMDL process.

1.2. Background

To help ensure safe and swimmable surface waters, routine monitoring for entero-pathogens is necessary. Direct monitoring of entero-pathogens, which can cause serious diseases such as cholera, typhoid, salmonellosis, and dysentery, is not feasible since these organisms are difficult to detect directly. Instead, an indicator organism, such as total coliforms, fecal coliforms, or *E. coli*, is used to determine fecal contamination. *E. coli* is a reliable indicator and is a subset of the fecal coliform bacteria group, which itself is a subset of the total coliform bacteria group. *E. coli* is considered a more specific indicator of fecal contamination than fecal coliforms since the more general test for fecal coliforms also detects thermotolerant non-*E. coli* bacteria (Francy et al., 1993).

E. coli bacteria, an intestinal organism of warm-blooded animals, are not typically pathogenic by themselves. However, an extensive epidemiological study (Dufour, 1984) showed that *E. coli* concentrations are one of the best predictors of swimming-associated gastrointestinal illness. IDEM water quality standards are based on a threshold concentration of *E. coli* in water, above which the health risk from waterborne illness is unacceptably high.

The presence of *E. coli* in surface waters is most often attributed to fecal contamination from agricultural and urban/residential areas. In addition, *E. coli* concentrations at a particular site may vary depending on the baseline bacteria level already in the river, inputs from other sources, dilution with precipitation events, and die-off or multiplication of the organism within the river water and sediments. The concentration of *E. coli* in surface water depends primarily on the runoff from various sources of contamination, and is related to the land use and hydrology of the watershed.

Sediments may affect the survival and can often act as a reservoir of *E. coli* in streams. This can lead to higher concentrations of *E. coli* in sediments than in the overlying water column (Burton et al., 1987). In addition, fecal bacteria may persist in stream sediments and contribute to concentrations in overlying waters for months after initial contamination, or can be resuspended due to a disturbance of the sediment, such as swimming or wading (Sherer et al., 1992).

The State of Indiana has only one recreational use category for all waters of the State, the highest, full body contact recreational waters. Indiana's water quality standard for recreational waters is set forth in 327 I.A.C. 2-1-6 and 2-1.5-8(e)(2): "*E. coli* bacteria, using membrane filter (MF) shall not exceed one hundred twenty five (125) per one hundred (100) milliliters as a geometric mean based on not less than five (5) samples equally spaced over a thirty (30) day period nor exceed two hundred thirty five (235) per one hundred (100) milliliters in any one (1) sample in a thirty (30) day period." The WFWR Data Report (Tetra Tech, 2002) presents the available *E. coli* data within the WFWR watershed and compares them to the water quality standard.

2. Point Sources

The term point source refers to any discernible, confined and discrete conveyance, such as a pipe, ditch, channel, tunnel or conduit, by which pollutants are transported to a water body. It also includes vessels or other floating craft from which pollutants are or may be discharged. By law, the term "point source" also includes concentrated animal feeding operations, which are places where animals are confined and fed. By law, storm water runoff from certain areas is also considered a point source because the water is transported through a pipe or ditch (see below).

Estimating the transport of *E. coli* into a surface water body from some point sources is a fairly straightforward matter. Both wastewater treatment plants (WWTP) and combined sewer overflows (CSOs) discharge though a constructed conveyance to a waterbody. Many of the organisms transported in this way are removed through treatment process, and permit limits are established to ensure that WWTPs meet water quality standards. However, in some instances failures or leaks may occur, or a wet weather event may create flows that exceed the capacity of the WWTP and therefore bypass treatment and are discharged directly to streams. This can lead to a discharge of *E. coli* contaminated water exceeding the permitted limits into the river system.

2.1. Wastewater Treatment Plants

Treated municipal sewage is a point source of bacterial contamination. Not all human pathogens are removed or rendered harmless by treatment processes. Raw sewage entering the WWTP typically has a total coliform count of 10,000,000 to 1,000,000,000 (1E+7 to 1E+9[†]) counts per 100 mL) (Novotny et al., 1989). Associated with raw sewage are proportionally high concentrations of pathogenic bacteria, viruses and protozoans. A typical wastewater treatment plant reduces the total coliform count by about three orders of magnitude. The magnitude of reduction, however, varies with the treatment process employed.

Treatment of municipal waste is generally identified as primary, secondary, or advanced (previously called tertiary treatment), although the distinctions are somewhat arbitrary. Primary treatment involves removing suspended solids with screens and the use of gravity settling ponds followed by disinfection. Most protozoan cysts settle out in ponds after 11 days due to their size (Environmental Microbiology, 1997). Secondary treatment uses biological treatment to decompose organic matter to cell material and by-products, and the subsequent removal of cell matter, usually by gravity settling. Activated sludge processes involve the production of an activated mass of microorganisms capable of stabilizing waste aerobically. Secondary treatment by activated sludge typically reduces coliform bacteria concentrations by 90 to 99 percent.

Tertiary treatment is any practice beyond secondary treatment and is very effective in destroying most pathogens. Tertiary treatment can include filtration, coagulants, and disinfection. Disinfection is the most common treatment technique to combat waterborne diseases, and the most frequently used disinfectant is chlorine (USEPA, 2001). Chlorine kills many microbes, including most pathogens, except protozoan cysts, which are resistant to chlorine. Other disinfectants used are ozone, ultraviolet light, and iodine.

As authorized by the Clean Water Act, the National Pollutant Discharge Elimination System (NPDES) permit program controls water pollution by regulating point sources that discharge pollutants into waters

[†] Because the counts of *E. coli* can be so large, scientific notation is typically used to express them. Scientific notation is a method scientists have developed to express very large numbers. Scientific notation is based on powers of the base number 10. The number 10,000,000 is written as 1×10^7 or 1E+7.

of the United States. The location of WWTPs with active NPDES permits in the WFWR watershed is presented in Figure 2 and the names of these facilities are shown in Table 2. There are currently 21 facilities that discharge *E. coli* to the WFWR or one of its tributaries (IDEM, 2002). Relevant statistics for conduit flow and *E. coli* reported by the facilities in their discharge monitoring reports (DMR) are presented in Tables 3 and 4. Annual *E. coli* loads for the facilities were estimated using the formula shown below and the resulting loads are presented in Table 5. A lack of flow and/or *E. coli* data for some of the smallest facilities prevented an estimate of their discharge of *E. coli*.

Annual Load (count/yr) = Flow (gal/month) x *E. coli* Concentration (count/100 mL) x 12 month/yr x Conversion Factor

Table 2. Permitted facilities in the WFWR which discharge *E. coli*.

NPDES Permit Number	Description	County
IN0020044	Alexandria Municipal Sewage Treatment Plant	Alexandria
IN0032476	Anderson Municipal Sewage Treatment Plant	Anderson
IN0032719	Elwood Municipal Sewage Treatment Plant	Elwood
IN0059943	Gasamerica, Hinkle Creek Wastewater Treatment Plan	Bakers Corner
IN0051951	Hamilton Western Utilities Inc	Carmel
IN0038857	I-69 Auto Truck Plaza Inc.	Muncie
IN0037133	Interventions, Inc.	Gaston
IN0038407	Jackson Mobile Home Park	Muncie
IN0061301	Mount Pleasant Utilities	Yorktown
IN0025631	Muncie Sanitary District	Muncie
IN0031640	Perry Elementary School	Selma
IN0039471	Quiet Acres Mobile Home Park	Selma
IN0053627	Resting Wheels Mob. Home Court	Anderson
IN0025364	Royerton Elementary School	Muncie
IN0038598	Suburban Estates Mobile Home Park	Noblesville
IN0025526	Tall Timber Mobile Home Park	Noblesville
IN0021474	Tipton Municipal Sewage Treatment Plant	Tipton
IN0031135	Union Elementary and High School	Modoc
IN0025151	Wesdel Jr-Sr High School	Gaston
IN0021024	Winchester Municipal Sewage Treatment Plant	Winchester
IN0020150	Yorktown Municipal Sewage Treatment Plant	Yorktown

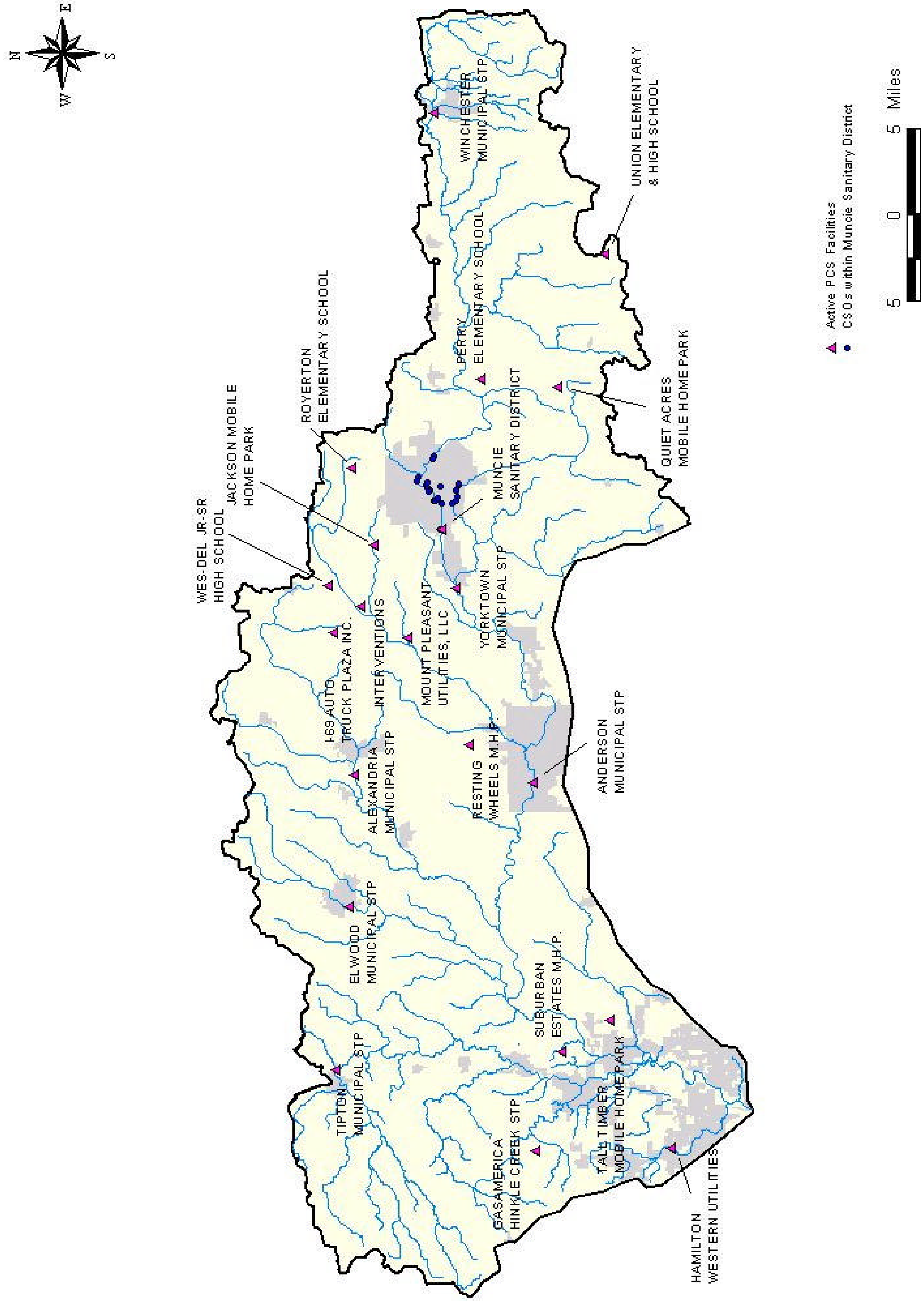

Figure 3. Location of permitted facilities and Muncie CSOs in the WFWR watershed.

Table 3. Summary of flow statistics for permitted facilities.

Description	Data Cover the Period		Number of Months Sampled	Average (MG/ month)	Maximum (MG/ month)
	From	To			
Alexandria Municipal Sewage Treatment Plant	May-97	Apr-02	60	30.67	54.55
Anderson Municipal Sewage Treatment Plant	May-97	Apr-02	418	431.67	739.90
Elwood Municipal Sewage Treatment Plant	May-97	Mar-02	58	81.06	110.61
Gasamerica, Hinkle Creek Wastewater Treatment Plan	Aug-97	Mar-02	27	0.08	0.22
Hamilton Western Utilities Inc	May-97	Apr-02	67	2.71	4.46
I-69 Auto Truck Plaza Inc.	Jun-98	Mar-02	45	0.20	0.34
Interventions, Inc.	Mar-98	Apr-02	55	0.18	0.50
Jackson Mobile Home Park	Jun-97	Apr-02	68	0.63	0.88
Muncie Sanitary District	May-97	Apr-02	360	829.90	10556.00
Noblesville Municipal Sewage Treatment Plant	Jun-98	Apr-02	46	80.01	122.85
Perry Elementary School	Sep-97	Mar-02	47	0.16	0.47
Quiet Acres Mobile Home Park	May-97	Apr-02	51	0.13	0.45
Resting Wheels Mob. Home Court	May-97	Apr-02	43	0.28	0.35
Royerton Elementary School	Jul-97	Mar-02	35	0.21	1.15
Suburban Estates M.H.P.	May-97	Apr-02	62	0.69	1.15
Tall Timber Mobile Home Park	Jul-97	Mar-02	36	0.26	0.94
Tipton Municipal Sewage Treatment Plant	May-97	Apr-02	120	40.61	60.52
Union Elementary & High School	May-97	Apr-02	44	0.15	0.64
Wesdel Jr-Sr High School	Jul-98	Mar-02	30	0.15	0.51
Winchester Municipal Sewage Treatment Plant	May-97	Apr-02	120	40.68	63.20
Yorktown Municipal Sewage Treatment Plant	May-97	Apr-02	120	29.65	46.83

MG = million gallons

Table 4. Summary of *E. coli* and Fecal Coliform concentration statistics for discharge from permitted facilities.

Description	Data Cover the Period		Number of Months Reported	Average (count/100 mL)	Max (count/ 100 mL
	From	To			
Alexandria Municipal Sewage Treatment Plant	4/30/1998	4/30/2002	29	13	7235

Anderson Municipal Sewage[±] Treatment Plant	5/31/1997	4/30/2002	35	30	333
Elwood Municipal Sewage Treatment Plant	4/30/2000	10/31/2001	14	61	3000
I-69 Auto Truck Plaza Inc	4/30/2001	4/30/2002	8	56	8000
Mount Pleasant Utilities Inc	7/31/2001	4/30/2002	5	143	1180
Muncie Sanitary District	4/30/1998	4/30/2002	102	28	25000
Noblesville Municipal Sewage Treatment Plant	5/31/1997	4/30/2002	35	37	308
Perry Elementary School	4/30/2001	4/30/2002	8	286	200000
Tipton Municipal Sewage Treatment	5/31/1997	4/30/2002	35	8	644
Winchester Municipal Sewage Treatment Plant	7/31/2000	4/30/2002	12	98	479
Yorktown Municipal Sewage Treatment Plant	5/31/1997	4/30/2002	35	7	184

[±] *E. coli* concentrations not reported in DMR therefore statistics are based on fecal coliform counts

Table 5. *E. coli* load estimates for permitted facilities in the WFWR watershed.

NPDES Permit Number	Description	Annual Loads (count/year)	Percent of Total
IN0020044	Alexandria Municipal Sewage Treatment Plant	7.83E+10	1.5%
IN0032476	Anderson Municipal Sewage Treatment Plant	4.84E+11[A]	9.3%
IN0032719	Elwood Municipal Sewage Treatment Plant	9.34E+11	17.9%
IN0038857	I-69 Auto Truck Plaza Inc	1.59E+09	0.0%
IN0061301	Mount Pleasant Utilities Inc	4.62E+08	0.0%
IN0025631	Muncie Sanitary District	3.26E+12	62.4%
IN0031640	Perry Elementary School	1.45E+09	0.0%
IN0021474	Tipton Municipal Sewage Treatment	5.95E+10	1.1%
IN0021024	Winchester Municipal Sewage Treatment Plant	3.71E+11	7.1%
IN0020150	Yorktown Municipal Sewage Treatment Plant	3.72E+10	0.7%
	Total	5.23E+12	100%

[A] *E. coli* data are not available for the Anderson treatment plant (only fecal coliform). Therefore the estimated load assumes that 25 percent of the fecal coliform counts consist of *E. coli*.

In addition to the discharge that reaches the stream after passing through the treatment plant, permitted facilities also report flow that bypasses treatment. Bypass flow may occur during intense wet weather events or under any other situation where the plant capacity is exceeded. During these events, wastewater is discharged directly into the stream with little or no treatment. Table 6 presents information on bypass flow volumes, days, and associated *E. Coli* loads for permitted facilities in the WFWR watershed. The loads are based on an estimated *E. Coli* concentration of 500,000 counts/100mL in wastewater, which accounts for minimal treatment (Powelson and Mills, 2001).

Table 6. Annual average by-pass flow information and *E. coli* loads.

NPDES Permit Number	Description	No of Bypass days/yr	Bypass flow (MG/yr)	Annual Loads[A] (count/year)
IN0020044	Alexandria Municipal Sewage Treatment Plant	22.3	--	--
IN0020168	Noblesville Municipal Sewage Treatment Plant	23.7	131.0	4.96E+09

IN0021474	Tipton Municipal Sewage Treatment	67.7	779.4	2.95E+10
IN0025364	Royerton Elementary School	0.3	--	--
IN0025631	Muncie Sanitary District	46.0	--	--
IN0032476	Anderson Municipal Sewage Treatment Plant	62.9	2870.6	1.09E+11
IN0032719	Elwood Municipal Sewage Treatment Plant	115.8	--	--

MG = million gallons
-- Bypass flow information was not available to calculate loads
[A] Assumes concentration in sewage of 500,000 counts/100mL (Powelson and Mills, 2001)

2.2. Combined Sewer Overflows

Combined sewer systems are sewers that are designed to collect rainwater runoff, domestic sewage, and industrial wastewater in the same pipe. Most of the time, combined sewer systems transport all of their wastewater to a sewage treatment plant, where it is treated and then discharged to a water body. During periods of heavy rainfall or snowmelt, however, the wastewater volume in a combined sewer system can exceed the capacity of the sewer system or treatment plant. For this reason, combined sewer systems are designed to overflow occasionally and discharge excess wastewater directly to nearby streams, rivers, or other water bodies. These overflows, called combined sewer overflows (CSOs), contain not only storm water but also untreated human and industrial waste, toxic materials, and debris. Because they are associated with wet weather events, CSOs typically discharge for short periods of time at random intervals.

Several communities in the WFWR watershed have CSO outfalls (Table 7). The location of CSOs within the Muncie Sanitary District are shown in Figure 3 and Table 8 provides an estimate of the annual load of *E. coli* from these CSOs. The annual volume of overflows and corresponding load of *E. coli* presented in Table 8 is from a 1998 study of the district (Huyck, 2002). The following equation was used to calculate the annual loads:

Annual Load (count/yr) = Volume of Overflow (gal/year) x Average *E. coli* Concentration reported for each CSO (count/100 mL) x Conversion Factor

Information on the location and characteristics of CSOs in the other communities have been requested but not yet received. They will be incorporated into the final TMDL report once they have been received. In the event that this information is not received, an average load per CSO outfall can be calculated based on Muncie data and used to estimate loads from other CSO communities.

Table 7. CSO Communities in the West Fork White River watershed.

Community	Number of CSO Outfalls
Alexandria	4
Anderson	19
Elwood	14
Muncie	22
Noblesville	7
Tipton	7

Table 8. Discharge information for combined sewer overflows in Muncie.

ID No	Description	Size (in)	Water Body	Estimated Annual Discharge (MG/yr)	Estimated Annual Load‡ (count/yr)
001	CL of Luick between edge of pavement and White River	18	White River	*	*
002	405 S. of Jackson St & W. of West edge of White River	30	White River	*	*
004	Intersection of Elm St. and McCulloch Blvd	12	White River	*	*
006	South Lane of Granville Ave. 118 S. of CL of Minnestrista	18	White River	*	*
007	25' E. of CL of Wheeling Ave. & 118' S. of CL Minestrista	36	White River	*	*
008	2 N of CL of North St. & on CL of Alameda Ave	12	White River	*	*
009	2' E of CL of Reserve St. and 216' S. of CL of North St.	12	White River	*	*
010	1 N of CL of Main St and 430 N of CL of Jackson St	8	White River	*	*
011	9 N of White River Blvd. And 425 S. of CL of Gilbert St	8	White River	*	*
012	CL of McKinley Ave. and 34 S. of CL of White River Blvd.	54	White River	*	*
013	50 N of CL of White River Blvd and on CL of College Ave	36	White River	*	*
015	At Beech Grove Cemetery	42	White River	235	3.92E+15
018	SW of CL of River Rd. and White River Blvd.	36	White River	148	2.21E+15
027	210 N of CL Kilgore Ave and 520 W of CL of Nichols Ave.	24	White River	*	*
028	100 S of CL Wheeling Ave and 200 E. of CL of Franklin St	42	White River	11.9	1.22E+14
022A	683 N of CL of 23rd St and 565 W. CL of Liberty St	72	Buck Creek	37.5	7.36E+14
022B	695 N of CL of 23rd St and 330 W of CL of Liberty St	72	Buck Creek	*	*
022C	690 N of CL of 23rd and 330 W of CL of Liberty St	27	Buck Creek	*	*
023	100 S of railroad tracks at end of extension of Elliot St	30	Buck Creek	*	*
024	73 E of CL of Cowan Rd an S. Bank of Buck Ck.	12	Buck Creek	1.9	1.05E+13
025	585 E of CL of 17th St. and 400 W. of CL of Rochester Ave	18	Buck Creek	*	*
026	Back yard of 1811 Thomas Drive	12	Buck Creek	*	*
			Total	434.3	6.99E+15

MG = million gallons

*These CSO outfalls are primarily for flood prevention during extremely intense rainfall events and have a very low probability of contributing *E. coli* loads (the probability associated with a recurrence interval greater than 20 yrs). Furthermore sewer separation has virtually eliminated discharges from CSO outfalls on the north side of the White River (except for CSO #018).

2.3. Storm Water Phase II Communities

Storm water runoff can contribute *E. coli* bacteria and other pollutants to a waterbody. Material can collect on streets, rooftops, parking lots, sidewalks, yards and parks and then during a precipitation event this material can be flushed into gutters, drains, and culverts and be discharged into a waterbody.

The U.S. EPA developed rules in 1990 that established Phase I of the NPDES storm water program. The purpose of this program is to prevent harmful pollutants from being washed by storm water runoff into Municipal Separate Storm Sewer Systems (MS4s) (or from being dumped directly into the MS4) and then discharged into local waterbodies. Phase I of the program required operators of medium and large MS4s (those generally serving populations of 100,000 or greater) to implement a storm water management program as a means to control polluted discharges from MS4s. Only the City of Indianapolis met Phase I criteria within the State of Indiana.

Under Phase II, rules have been developed to regulate most MS4 entities (cities, towns, universities, colleges, correctional facilities, hospitals, conservancy districts, homeowner's associations and military bases) located within mapped urbanized areas, as delineated by the U.S. Census Bureau, or, for those MS4 areas outside of urbanized areas, serving an urban population greater than 7,000 people. The following entities within the WFWR watershed fall under the Phase II guidelines:

- Anderson
- Arcadia
- Muncie
- Carmel
- Fisher
- Noblesville
- Parker City
- Selma
- Yorktown
- Westfield
- Hamilton County
- Madison County
- Delaware County
- Randolph County

Operators of Phase II-designated small MS4s are required to apply for NPDES permit coverage and to implement storm water discharge management controls (known as “best management practices” (BMPs)).

Loads of *E. coli* from urban storm water sources in the WFWR watershed will be quantified during the modeling phase of the TMDL and are not available at the time of this report. A description of the modeling approach will be presented in a forthcoming Modeling Framework Report.

2.4. Confined Feeding Operations

Indiana law defines a confined feeding operation as any livestock operation engaged in the confined feeding of at least 300 cattle, or 600 swine or sheep, or 30,000 fowl, such as chickens, ducks and other poultry. IDEM regulates these confined feeding operations, as well as smaller livestock operations which have violated water pollution rules or laws, under IC 13-18-10, the Confined Feeding Control Law. Draft rules regulating confined feeding were re-adopted by the Water Management Board on November 14, 2001 and became effective on March 10, 2002.

The animals raised in confined feeding operations produce manure that is stored in pits, lagoons, tanks and other storage devices. The manure is then applied to area fields as fertilizer. When stored and applied properly, this beneficial re-use of manure provides a natural source for crop nutrition. It also lessens the need for fuel and other natural resources that are used in the production of fertilizer. Confined feeding operations, however, can also pose environmental concerns, including the following:

- Manure can leak or spill from storage pits, lagoons, tanks, etc.
- Improper application of manure can contaminate surface or ground water
- Manure overapplication can adversely impact soil productivity.

Although confined feeding operations themselves are point sources, the runoff of applied manure is a nonpoint source. Therefore the discussion of confined feeding operations in the WFWR watershed is presented in section 3.2.

3. Nonpoint Sources

Nonpoint sources of pathogens are much more difficult to identify and quantify than are point sources. In urban areas, nonpoint sources can include leaking or faulty septic systems, landfill seepage, pet waste, storm water runoff (outside of Phase II communities), and other sources. In more rural areas, major contributors can be pasture land runoff, manure storage and spreading, concentrated animal feedlots, and wildlife.

3.1. Septic Systems

Septic systems that are properly designed and maintained should not serve as a source of contamination to surface waters. However, septic systems do fail for a variety of reasons. Common soil-type limitations in central Indiana which contribute to failure are: seasonal water tables, compact glacial till, bedrock, coarse sand and gravel outwash and fragipan. When these septic systems fail hydraulically (surface breakouts) or hydrogeologically (inadequate soil filtration) there can be adverse effects to surface waters down gradient (Horsely and Witten, 1996).

Another issue regarding certain septic systems in Indiana is that some are illegally connected to tile-drainage pipes in agricultural watersheds, providing a direct source of fecal matter to streams. A recent survey of county health officials (Taylor et al., 1997) found that up to 80 percent of countywide septic systems were either failing or illegally connected to ditches or tile lines. In addition, most homes built prior to 1980 in rural areas do not have absorption fields.

Site-specific information on the location of failing or illicitly connected septic systems is not currently available for the WFWR watershed. Therefore estimates of the loads of *E. coli* from these sources must be based on the assumptions outlined below:

- Total number of septic systems (derived from US Census 1990 and 2000)
- Assume 2.5 percent of all systems are within 100 feet of a perennial stream (derived from a GIS analysis)
- Estimated population served by the septic systems (an average of 2.5 people per household, US Census 2000)
- An average daily discharge of 265 liters/person/day (Horsley and Witten, 1996)
- Septic effluent *E. coli* concentration of 1,000,000 (1E+6) counts/100 ml (Powelson and Mills, 2001)
- Average septic failure rate (including systems illegally connected to tile drains) of 40 percent (Taylor et al., 1997)

The calculations used to estimate *E. coli* loads from these systems is:

Annual Load (count/yr) = Number of Systems within 100 Feet of a Stream x Percent Systems Failing x 2.5 Persons Served per System x 265 L/Person/Day x 1E+6 counts/100 mL x 365 Days/Year x 10 (Conversion Factor)

Table 9 presents the *E. coli* bacteria loading from septic systems calculated using the above information. The loads are presented for the area of each county that is in the WFWR watershed. County specific data will be included in the modeling of septic contributions. For example, data provided by Hamilton County identifies the location of areas with high septic vulnerability. Similar information has been requested from Delaware County. The model will take this type of specific spatial distribution information into account.

Table 9. Estimates of septic loading per county in the WFWR watershed.

County	Number of Households (2000 Census)	Estimated Number of Households in WFWR Watershed (2000 Census and GIS Analysis)	Percent of Housing Units with Septic Systems (1990 Census)	Estimated Number of Households with Septic Systems	Load from Septic Systems (count/yr)
Delaware	51,032	33,680	21.88%	7,369	1.78E+14
Hamilton	69,478	51,464	28.52%	14,678	3.55E+14
Henry	20,592	3057	42.97%	1,313	3.17E+13
Madison	56,939	37,402	29.83%	11,157	2.70E+14
Randolph	11,775	4,091	44.65%	1,826	4.42E+13
Tipton	6,848	2,793	54.36%	1,518	3.67E+13
Total	218,664	134,487	--	37,861	9.16E+14

3.2. Agriculture

Lands used for agricultural purposes can be a source of *E. coli* bacteria. Runoff from pastures, livestock operations, improper land application of animal wastes, and livestock with access to waterbodies are all potential agricultural sources of *E. coli*.

Animals grazing in pasturelands deposit manure directly upon the land surface. Even though a pasture may be relatively large, and animal densities low, manure will often be concentrated near the feeding and watering areas in the field. These areas can quickly become barren of plant cover, increasing the possibility of contaminated runoff during a storm event. The occurrence and degree of *E. coli* loads from livestock are linked to temporally and spatially variable hydrologic factors, such as precipitation and runoff–except when manure is directly deposited into a waterbody (USEPA, 2001).

The application of manure that has been improperly composted can contribute bacteria that are conveyed into surface water during runoff events. Animal wastes must be handled, stored, utilized and/or disposed of in an efficient way to avoid this problem because bacterial content of animal waste varies with collection, storage and application methods. Manure in the WFWR watershed is applied to both cropland and pasture land.

Grazing animals, confined animal operations and manure application are all potential sources of *E. coli* in the WFWR watershed. The number of livestock estimated to be in the watershed is derived from data available from the latest agricultural census (1997), which is shown in Table 10. The number of livestock in the watershed is based on either (1) site-specific estimates made by local U.S. Department of Agriculture officials or (2) the proportion of the county that overlaps the watershed.

The number of livestock associated with confined feeding operations in the WFWR watershed is shown in Table 11. Indiana law defines a confined feeding operation as any livestock operation engaged in the confined feeding of at least 300 cattle, or 600 swine or sheep, or 30,000 fowl, such as chickens, ducks and other poultry. IDEM regulates these confined feeding operations, as well as smaller livestock operations which have violated water pollution rules or laws, under IC 13-18-10, the Confined Feeding Control Law.

Table 10. Agricultural census information for the counties within the WFWR watershed (USDA, 1997).

County	Number of Beef Cows	Number of Milk Cows	Number of Other Cattle	Number of Total Cattle	Number of Hogs and Pigs	Number of Sheep and lambs
Delaware	1,591	569	2,697	4,857	24,502	506
Hamilton	1,480	294	2,493	4,267	24,010	900
Madison	2,299	104	4,082	6,485	26,111	785
Randolph	1,850	845	5,167	7,862	50,936	1,039
Tipton	NA	NA	--	2,004	56,821	445
Total	7,220	1,812	14,439	25,475	182,380	3,675

Table 11. Confined feeding operation information for the WFWR watershed.

County	Number of Beef Cows	Number of Dairy Cows	Number of Veal	Number of Swine	Number of Chickens	Number of Turkeys	Number of Ducks	Number of Sheep
Delaware	0	0	0	30,958	0	0	0	0
Hamilton	50	50	0	19,657	0	0	0	0
Madison	905	1,200	0	28,549	0	0	0	0
Randolph	40	50	0	61,244	100,000	0	0	0
Tipton	1,150	0	0	41,504	288,000	0	0	0
Total	2,145	1,300	0	181,912	388,000	0	0	0

EPA's Fecal Load Estimation Spreadsheet Tool was modified for *E. coli* and used to estimate the amount of *E. coli* bacteria introduced directly to streams in the WFWR watershed, as well as estimate accumulation rates of *E. coli* bacteria on the land surface. The tool quantifies the *E. coli* bacteria component of waste generated by warm-blooded animals and distributes these quantities to streams and to the land surface based on land use type.

The following assumptions were made to calculate existing *E. coli* loads and accumulation rates. The assumptions are based on default values in EPA's Estimation Spreadsheet Tool complemented by discussions with local U.S. Department of Agriculture officials. The assumptions can be further modified based on additional local input as it becomes available.

- Cattle manure is applied to both cropland and pasture. A maximum of 75 percent of the manure that is applied is available for runoff to account for infiltration, incorporation into soil, and *E. coli* die-off.
- When grazing, fifty percent of the cattle can be assumed to have direct access to streams. Therefore cattle waste is transported to surface waters through surface runoff or is contributed directly to streams.
- Cattle are either kept in feedlots or allowed to graze during specified months (depending on the season). We assumed that cattle graze 25 percent of the time in the winter and 75 percent of the time during other seasons. During grazing, cattle spend 0.15 percent of their time directly in the stream, which is equivalent to 9.8 hours over the course of one year.
- No manure is imported into the watershed.

Loads presented in Table 11 were calculated using the following equation:

Annual Load (count/season) = Animals with Access to Stream x Waste Production Rate (grams/animal/day) x *E. coli* Count in Waste (count/gram) x # days/season

Table 12. Estimated accumulation rates for pastureland and loadings from in-stream cattle.

Season	*E. coli* Accumulation Rate (count/ac/yr)		Direct loading (count/season)
	Cattle	Hogs	Cattle in streams
Winter	5.40E+11	1.76E+14	2.67E+14
Autumn, Summer, Spring	4.88E+12	3.13E+14	8.00E+14

3.3. Wildlife

Wildlife living in the watershed can often contribute *E. coli* into the waterbody. Many animals spend time in, or near, waterbodies. Raccoons, deer, waterfowl, beaver, muskrat, rabbits, squirrels, and other animals all create potential sources for fecal bacteria contamination. One method to differentiate between all of the potential sources is to use DNA fingerprinting of the *E. coli* bacteria present in the waterbody, and match the results with a library of *E. coli* strands. This allows an estimation of the amount of pollution coming from which species. However, this methodology is not an available resource to this TMDL because it is costly and requires the development of a location-specific DNA library. Another method is to estimate the wildlife population and the amount of *E. coli* that each organism may contribute and model the results.

The Indiana Department of Natural Resources estimates that the Canadian geese population has increased dramatically in the past two decades and is approaching estimates of 100,000 birds statewide (IDNR, 2003a). Canada geese readily use urban habitats around apartments, office complexes and golf courses. They also inhabit areas near water and wetlands.

Raccoons are found throughout Indiana. They are most numerous where a good mixture of woodlands, cropland, and shallow water are found. The fertile farmland of central Indiana is home for many raccoons. Under ideal conditions, raccoon levels can approach one per acre. Even in less favorable habitat, they still may occur at the rate of about one raccoon per 40 acres.

The white-tailed deer are Indiana's sole representative of the family Cervidae, which includes mule deer, elk and moose. White-tailed deer occupy both forest and non-forest habitat types throughout Indiana. Population estimates are available from the Indiana Department of Natural Resources (IDNR, 2003b).

Wildlife contributes to the potential impact of contaminated runoff from animal habitats, such as urban park areas, forest and cropland. Actual loads are dependent on hydrologic factors. Estimates of the impact potential associated with landuse and wildlife can be made in terms of bacterial cell count per acre per year (count/ac/yr). Some assumptions are necessary to compute these estimates, including the following:

- Animal count, density and distribution
- *E. coli* content of animal waste (available from the literature)
- Daily waste production of each animal

The results of the estimates for the WFWR watershed are shown in Table 12. Statewide wildlife animal numbers watershed were obtained through Indiana's Department of Natural Resources (DNR) webpage. Assuming an even distribution of animals throughout the relevant landuses over the state and WFWR animal densities were obtained. Loads were then calculated using the formula

Annual Load (count/yr) = Animal Density (number of animals/acre) x E. coli Production Rate (count/animal/day) x Area of Impacted Landuse (acres) x 365 days/year

Table 13. Estimated loadings from wildlife in the WFWR watershed.

Animal	EC (count/animal/ day)	Animal Count (number/ac)	Accumulation Rate (count/ac/yr)	Impacted Landuse
Geese	5.38E+08[a]	0.0043[c]	1.18E+13	Wetlands, Urban Grasses
Deer	4.32E+09[b]	0.0167[c]	9.21E+15	Forest, Grassland, Pasture and Cropland
Raccoon	1.60E+08[b]	0.0300[c]	6.55E+14	Forest and Cropland

[a] Roll and Fujioka (1997)
[b]. Estimate based on *E. coli* literature
[c]. IDNR estimate

3.4. Domestic Pets

Domestic pets can be potential sources of *E. coli* much in the same way that wildlife can. Cats and dogs can contribute fecal material within the watershed that may find its way into the waterbody, and could harbor living *E. coli* bacteria. This source is more likely in more populated areas where large numbers of pets are to be found.

A 1999 national study reported that 39 percent of households own at least one dog and 32 percent own at least one cat. Since there are an estimated 134,487 households in the watershed, approximately 52,450 own dogs and 43,035 own cats. The average number of dogs per dog-owning household is 1.41 and the average number of cats per cat-owning household is 2.4 Using these values results in an estimate of 73,430 dogs and 103,284 cats. The *E. coli* loads from these animals will be captured in the modeling of urban and residential areas.

4. Conclusions

A full evaluation of the sources of *E. coli* in the WFWR watershed cannot be completed at this time. Information is not yet available on the CSOs in Alexandria, Anderson, Elwood, Noblesville, and Tipton and the loads from storm water runoff and other land uses will not be quantified until the watershed modeling is complete. However, Table 14 presents the results of the preliminary analysis.

Several initial conclusions can be drawn from Table 14. First, CSOs are contributing the largest *E. coli* loads compared to the other source categories evaluated. The current estimate of *E. coli* from CSOs throughout the watershed is based on the assumption that the average per outfall load from Alexandria, Anderson, Elwood, Noblesville, and Tipton is similar to that from Muncie. Even if the average per outfall load is half that of Muncie (which is unlikely), CSOs remain the largest of source categories evaluated.

Septic systems and cattle are contributing the next greatest amount of *E. coli* compared to the other source categories evaluated. The estimated load is based on a number of assumptions, of course, but the results do not change dramatically even if some of the assumptions are changed significantly. For example, if only 20 percent of the septic systems are failing (instead of the assumed 40 percent) the load from septic systems is still more than that from the wastewater treatment plants or the bypasses. Cattle in streams are the next greatest source of *E. coli* loading among those evaluated. They remain the second greatest source (of the categories evaluated) even if only 10 percent of the cattle instead of 50 percent have direct access to streams.

It is important to note that the information provided in Table 14 only addresses the waste generation and potential transport of *E. coli* in the watershed. It does not address the impact of the sources on resulting water quality. Loads from some of the sources, such as CSOs and storm water runoff, will be driven by wet weather events. During such events the flow in the streams will provide some dilution of the bacteria load. Loads from other sources, such as cattle, septic systems, and wastewater treatment plants, will continue during low flow conditions when there is less dilution capacity in the stream. These factors and others that affect instream conditions will be explored further during the modeling process.

Table 14. Preliminary estimates of the sources of *E. coli* in the WFWR watershed.

Source Category	*E. coli* Loading (count/yr)
Cattle in Streams	6.67E+14
Combined Sewer Overflows[A]	2.32E+16
Septic Systems	9.16E+14
Storm Water Runoff from Manured Lands	NA
Storm Water Runoff from Other Land Uses	NA
Storm Water Runoff from Phase II Communities	NA
Wastewater Treatment Plant Discharge	5.23E+12
Wastewater Treatment Plant Bypasses	1.43E+11

[A] Initial estimate assuming that average loads from CSOs in Muncie are representative of other communities.

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